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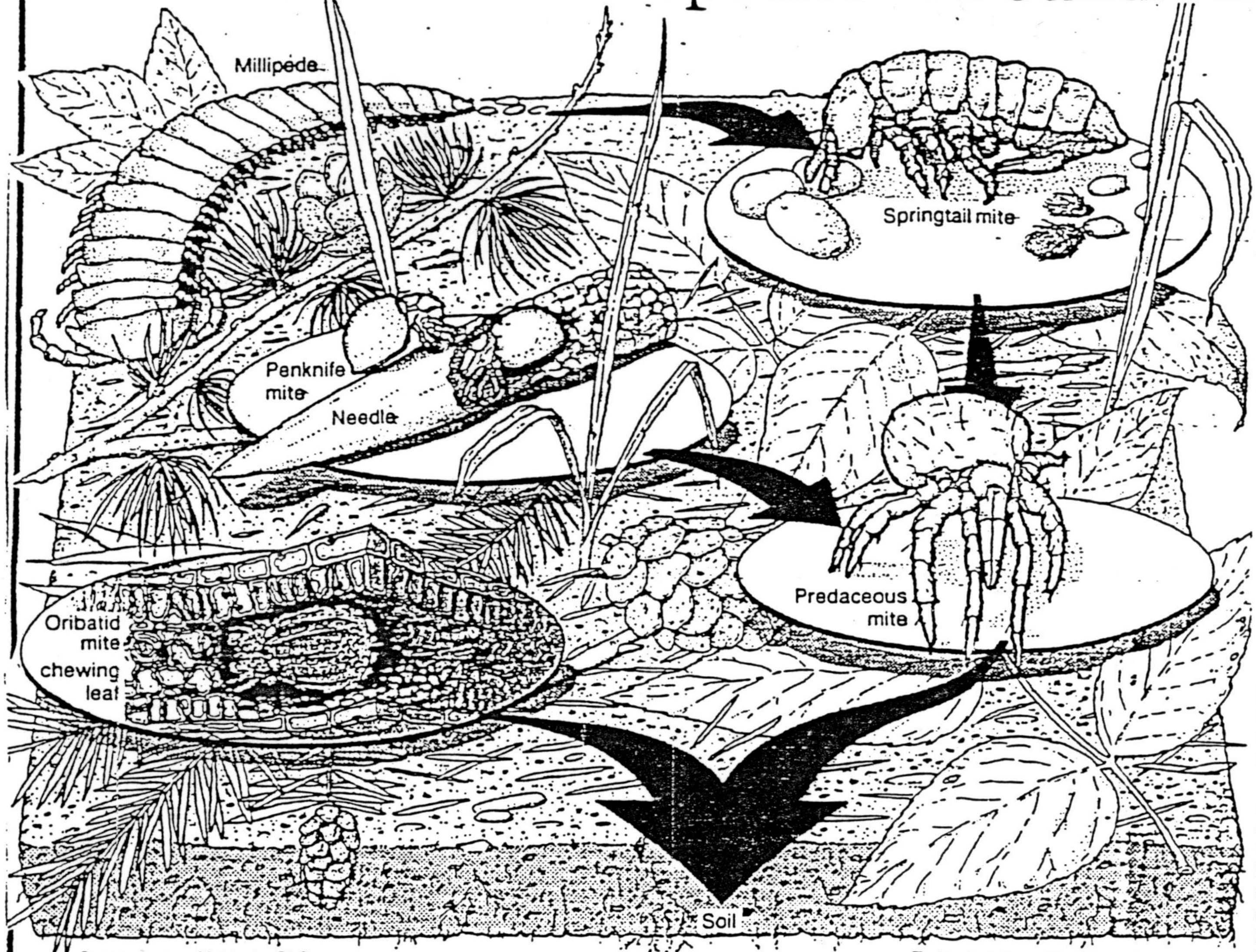
A Wealth of Forest Species Is Found Underfoot



Source: Andrew Moldenke, Ph.D.

The New York Times: Illustration by Thomas C. Moore

Manufacturing Fertility for the Forest's Soil

Tiny creatures eat forest debris, and each other, in a process that breaks plant matter into smaller and smaller pieces and exposes it to decomposer bacteria. A millipede devours a pine needle; its feces feed a springtail mite. A penknife mite also eats pine needles. A predaceous mite feeds on other mites. An oribatid mite eats leaves.

Army of tiny creatures recycles forest detritus.

By JON R. LUOMA

ENVIRONMENTALISTS have focused great attention on spotted owls and ancient trees in the forests of the Pacific Northwest. But a small cadre of researchers who have been studying insects and other invertebrates of the forest soil now say that the old-growth forest has been hiding underfoot perhaps its most astonishing biological secret.

Detailed studies of arthropods including insects, spiders, mites and centipedes in the soil of the old-growth forest suggest that the soil under the region's forest floor is the site of some of the most explosive biological diversity found on earth. Some experts believe that these temperate forests harbor a diversity of species that approaches the much-touted biological diversity of tropical rainforests.

As part of one of the most detailed analyses of arthropod diversity ever conducted, scientists now estimate that about 8,000 distinct species inhabit a single study site in an Oregon old-growth forest, most of them in the soil. The findings are "especially surpising because we think of that kind of diversity as being related to the tropics, not the temperate forests," said Melody Allen, executive director of the Xerces Society, an invertebrate conservation group.

But scientists say that those num-

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In Old-Growth Forests, a Wealth of Species Is Found Underfoot

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bers are far less significant than still-sketchy hints of the role insects and other arthropods apparently play in the temperate forest ecosystem. "We've come to suspect that these invertebrates of the forest soil are probably the most critical factor in determining the long-term productivity of the forest," said Dr. Andrew Moldenke, an entomologist Oregon State University in Corvallis.

In tropical rainforests, twigs, fallen leaves and dead organisms are decomposed rapidly by bacteria and fungi that thrive in the warm, wet ecosystem. But in the temperate forests of the Pacific Northwest, arthropods appear to be linchpins in the decomposition process.

Billions of extremely tiny insects, mites, "microspiders" and other invertebrates serve as biological recycling engines that reduce tons of organic litter and debris, from logs to bits of moss that fall to the forest floor, into finer and finer bits. Bacteria and fungi living in the digestive tracts of the arthropods and in the soil then progressively reprocess the finely crushed, once-living tissue into basic nutrient chemicals to feed roots and, hence, the above-ground ecosystem.

New techniques for solidifying and examining soil samples offer great promise in increasing understanding of the rich ecosystems in the forest soil. Researchers caution that they still know "almost nothing" about precisely how all the thousands of arthropods interact and survive.

Taxonomists working in the region have been able to identify about 3,400 arthropod species at a single research site, the H. J. Andrews Experimental Forest in Oregon, a sort of living forest laboratory operated by the United States Forest Service. Many of those species have never before been named and described. In comparison, the count of all species of reptiles, birds, and mammals combined at the site is 143.

plished by insinuating, in a pressure chamber, epoxy into a carefully removed core of soil. Once the epoxy hardens, the now rock-like soil sample can be sliced into exceedingly thin wafers and polished smooth for examination under a microscope.

The technique preserves the soil with its parts in place, from larger bits of partly decayed plant matter to microscopic soil particles. On one such slide, Dr. Moldenke showed a visitor the image of what was clearly a needle from a coniferous tree, partly decayed, but still mostly intact.

Magnified, however, the small needle in the soil turn out to be an assemblage of thousands of infinitesimal fecal pellets arranged in almost precisely the shape of the needle. Not long after a bit of vegetation falls, millipedes descend on it, grinding it up. Chewed-up bits of vegetation pass through the insects' digestive tracts in a matter of seconds and are redeposited virtually in place as a pellet.

A closer microscopic look at each pellet reveals that each is nothing more than chopped-up bits of plant cells, reassembled into a sort of jigsaw puzzle of plant matter. These tiny clumps of cell tissue will, in turn, be eaten by other arthropods.

Working in turn, tiny creatures gradually turn insoluble cells into nutrients.

Deeper in the soil, the jigsaw-like cell-tissues become progressively less recognizable, as successive waves of "microshredder" arthropods crush and partly digest these fecal pellets, like a series of minute millstones grinding food down to finer and finer bits.

Cell tissue cannot dissolve in water. Yet for a living ecosystem to perpetuate itself, nutrient chemicals that are locked into insoluble organic molecules in tissues of dead organisms must somehow be made soluble to be taken up by the roots of plants.

Each arthopod extracts only the whisper of nutrition from food that was once living cell matter. But in the process, each arthropod exposes more surface area to decomposer bacteria. The bacteria, in turn, biochemically process a trace more cell matter on the pellet's surface into soluble compounds, making more nutrition available to the next arthropod until, eventually, insoluble cell matter becomes soluble nutrients

In the old-growth forest, the process is sometimes excruciatingly slow. Soil organisms are just now completing the decomposition of some giant trees that crashed to earth about the time Columbus sighted land.

Precisely how all these biological and chemical interactions occur, and which of the thousands of species' survival is key to the survival of others, are matters that remain poorly understood. "We've reached the point where we know just a little bit more about the fauna of the forest soil at the end of the the 20th century than was known at the beginning of the 19th," Dr. Moldenke said.

Mysterious Diversity

And researchers still don't know why there are so many invertebrate species in the forest soil first place. "There are still a lot of questions about why there's so much diversity," said Dr. Lattin. "But the fact that they are out there in such great numbers suggests that they play a very, very important role in the ecosystem."

Dr. Moldenke agreed. "I don't know what the implications of all that diversity are," he said. "Neither does anybody else. And that's the scary part. I guess what concerns us is that the kinds of above-ground ecosystems that most ecologists have studied in the past is a very small part of what's really out there.

"When you have an awful lot of species, it means almost by definition a great number of processes: thousands of different functions taking place. If we instead continue to manage forests on the basis that the ecosystem is much more simple than it really is, we may be setting ourselves up for a big surprise, and it may not be a nice surprise"

One potential practical benefit of all that diversity lies on the research horizon: the arthropod communities may be able to serve as an exquisitely tuned gauge of changes in the forest ecosystem.

In 1988, Dr. Moldenke began plugging data about the tens of thousands of arthropods collected from dozens of sites into a computer for statistical analysis. The results were so surprisingly consistent that he worried that the computer had been misprogrammed. Computer analysis proved that by analyzing the thousands of arthropods in a tin can full of soil from a site, a researcher could predict with accuracy the condition of the site itself.

"As a result of knowing that pattern, anyone could take a sample in the Andrews Forest find out what time of year it was taken, whether it came from a north or south slope, what the moisture content of the soil was," Dr. Moldenke said. "In some areas, it could tell you what kind of tree was nearby and how far away."

Mighty Mites

As a simplified example, he says, an abundance of tiny mites called Eulohmannia, which are "bright orange-yellow and look like a gasoline truck," indicate that a site is relatively dry and in a young forest. On the other hand, an abundance of Eremaeus mites, which "look like turtles with a pattern of red dots," indicates a moist site in old-growth forest.

By analyzing such characteristics among thousands of arthropod data-points, a researcher may be able to monitor changes at a site brought on by, say, global warming or herbicide use

"A tree doesn't tell you too much about what's happening," said Dr. Moldenke. "If you want to monitor change in the environment, the worst thing to look at is an organism that's centuries old. But the arthropod community allows to look at what's happened over a different time frame, as little as a few months. And you can only do that because you have all that diversity."

Catalogue Is Only Begun

Yet, according to Dr. John Lattin, director of the Systematic Entomology Laboratory at Oregon State University, the number of species catalogued so far probably represents less than half of the estimated species present on just the Andrews Forest site.

"Simply to describe and name the yet-unnamed species will take years, in part because the sheer numbers of arthropods in even a small area, according to Dr. Lattin. Most of the soil arthropods are exceedingly small, as tiny as 1 or 2 one-hundredths of an inch long. That is as small as or smaller than the period at the end of this sentence. And surveys have shown that the soil under a single square yard of forest can hold as many as 200,000 mites from a single sub-order of mites, the oribatids, not to mention tens of thousands of other mites, beetles, centipedes, pseudo-scorpions, springtails, "micro-spiders" and other creatures.

Dr. Moldenke and his students have in recent years begun studying soil and arthropod ecosystems using a technique called thin-section microscopy, originally developed by oil-exploration geologists. That approach has revealed that the very structure of temperate forest soils, and hence much of their biological and chemical activity, is determined by the dietary habits of the soil arthropods.

Thin-section microscopy is accom-